



Status of MODIS and VIIRS Instruments

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Acknowledgements:

MODIS Characterization Support Team (MCST)

VIIRS Characterization Support Team (VCST)

Outline

- **Introduction**
 - MODIS and VIIRS Instruments
 - Calibration Approaches
- **MODIS and S-NPP VIIRS On-orbit Performance**
- **MODIS L1B and S-NPP VIIRS SDR (L1B)**
- **Summary**

Introduction

- **MODIS on Terra and Aqua Missions**
 - Terra: Dec. 18, 1999 – Present
 - Aqua: May 04, 2002 – Present
- **VIIRS on S-NPP and JPSS Missions**
 - S-NPP: Oct. 28, 2011 – Present
 - JPSS-1: launch in Jan 2017
 - JPSS-2: launch in July 2021

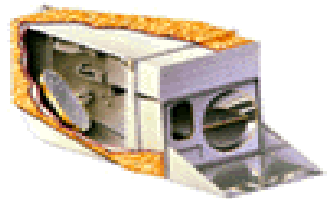
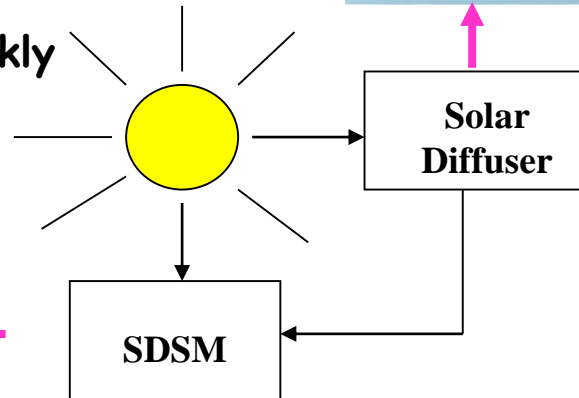


CERES

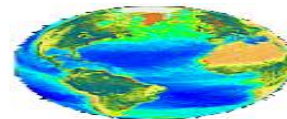


MODIS On-orbit Calibration Methodologies

SD/SDSM:
Weekly to tri-weekly



Scan Mirror



Spacecraft maneuvers:
Yaw (SD BRF, VF)
Roll (Moon)
Pitch (only applied to Terra)

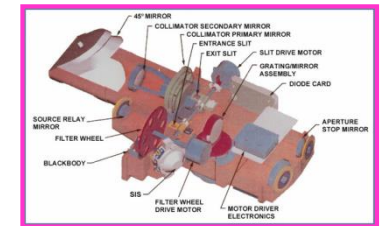
SRCA

Blackbody

Space View



SRCA:
Radiometric: monthly
Spatial: bi-monthly
Spectral: quarterly



BB: quarterly

Moon: monthly (nighttime orbits)
0-20° spacecraft roll maneuvers
55° phase angle

VIIRS operation/calibration strategies are similar to MODIS (no SRCA in VIIRS)

Terra and Aqua MODIS On-orbit Performance

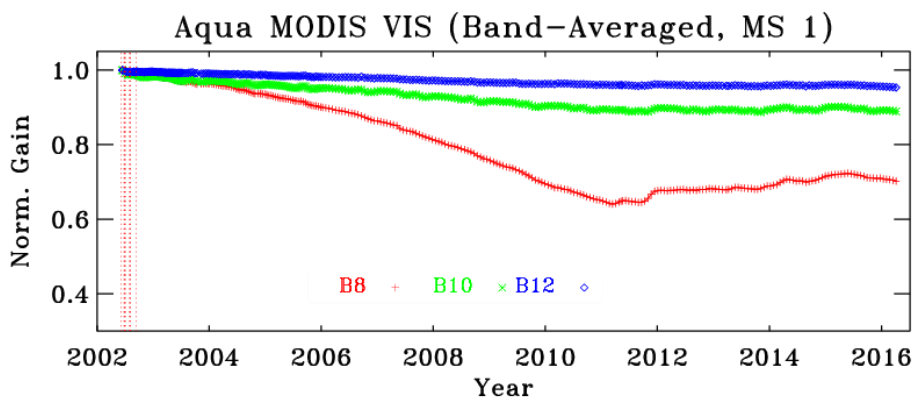
- SD degradation: wavelength-dependent (larger at shorter wavelength; faster with more solar exposure)
- BB stability: excellent (more stable in Aqua)
- Changes in detector responses
 - Large changes in VIS and NIR (strong wavelength and AOI dependent)
 - Small changes in SWIR, MWIR, and LWIR
- Changes in responses versus scan-angle (RVS): RSB only
- Changes in polarization characteristics (primarily in Terra VIS bands): science impact
- Spatial and spectral: stable through entire missions
- **Terra safe hold event (2/18/16)**
 - Nominal operation resumed
 - Additional noisy detectors (21 of the 26 noisy detectors since launch are in LWIR PV bands; 11 of the 21 occurred after safe hold event)

S-NPP VIIRS On-orbit Performance

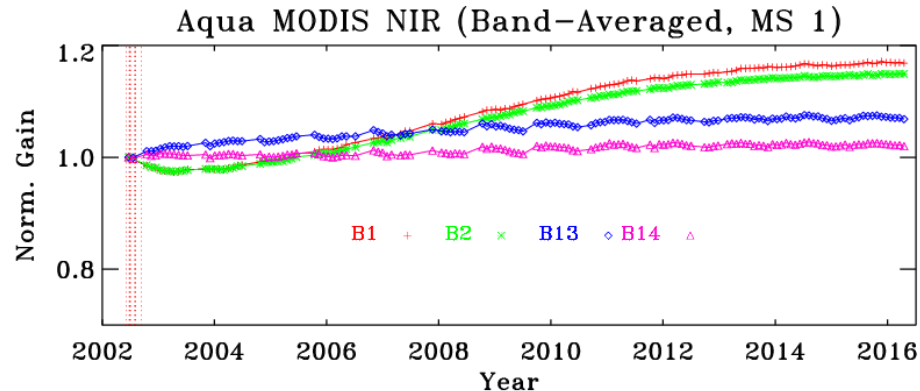
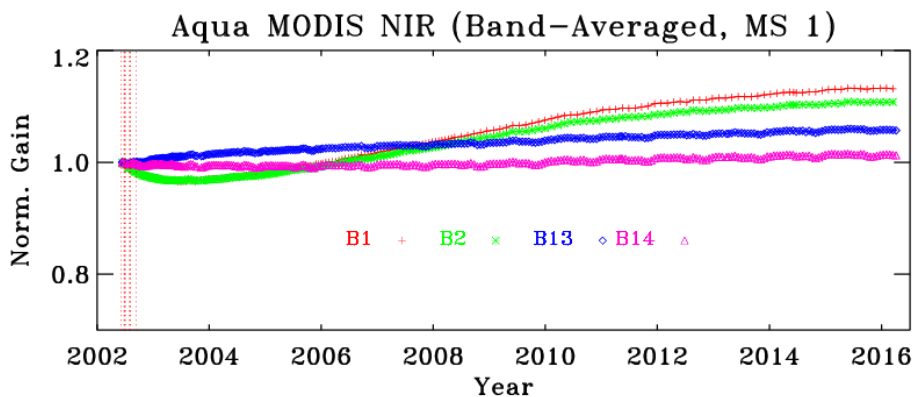
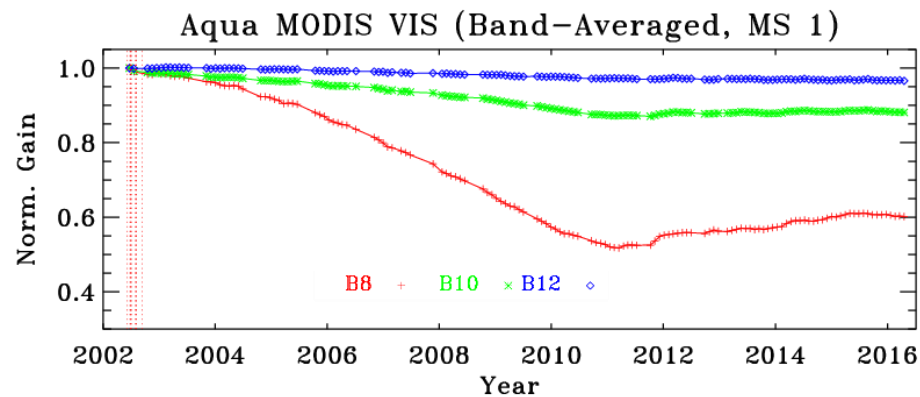
- SD degradation: similar to Terra MODIS
- BB stability: similar to Aqua MODIS
- Changes in detector responses
 - Large changes in NIR and SWIR (due to mirror contamination)
 - Small changes in VIS, MWIR, and LWIR
- Changes in responses versus scan-angle (RVS): small
 - Monitored using EV data at different AOI
- Spatial performance: stable through entire mission
 - Tracked using lunar observations (no SRCA)
- Spectral performance: modulated RSR
 - **VIIRS unique feature**
 - Mirror contamination => wavelength dependent optics degradation

Aqua MODIS VIS/NIR Radiometric Responses

SD View (AOI=50.2°)



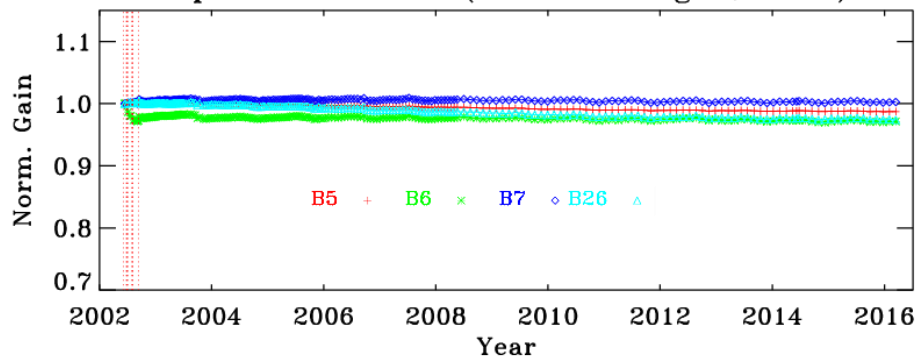
SV View (AOI=11.2°)



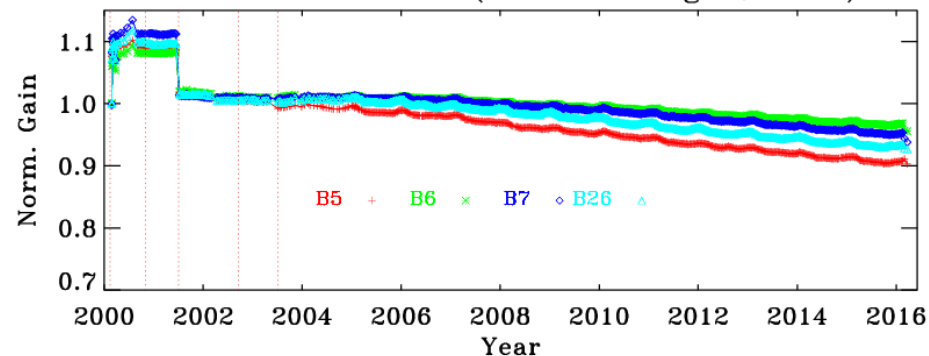
Similar λ , AOI, and mirror side dependence for Terra MODIS VIS and NIR responses

MODIS SWIR, MWIR, and LWIR Radiometric Responses

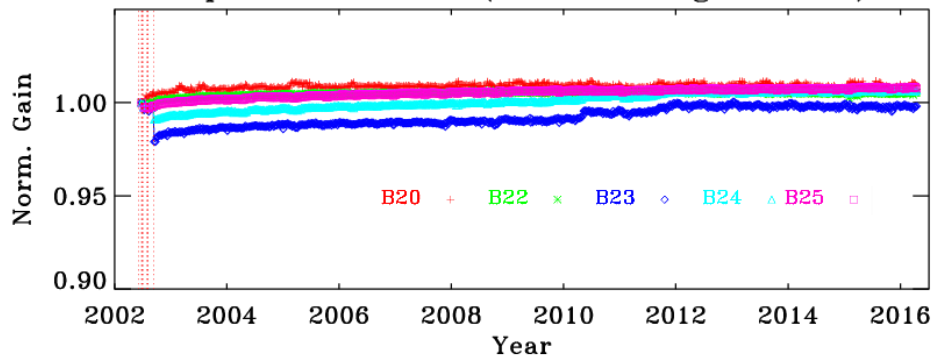
Aqua MODIS SWIR (Band-Averaged, MS 1)



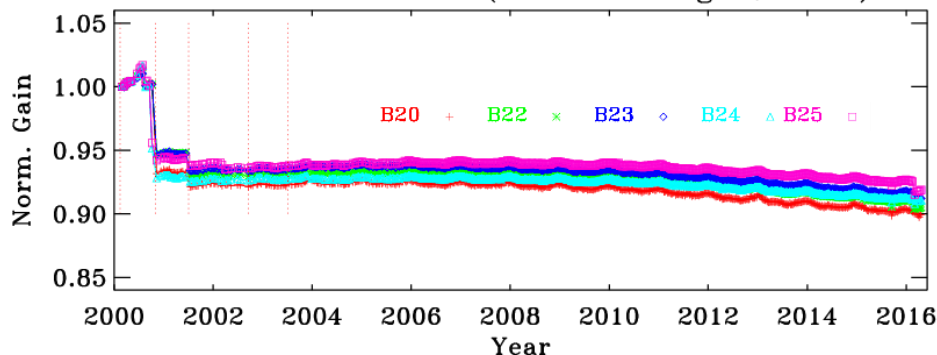
Terra MODIS SWIR (Band-Averaged, MS 1)



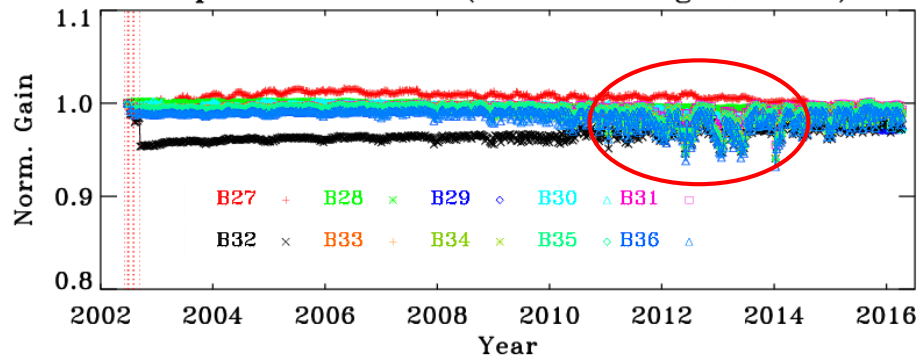
Aqua MODIS MWIR (Band-Averaged, MS 1)



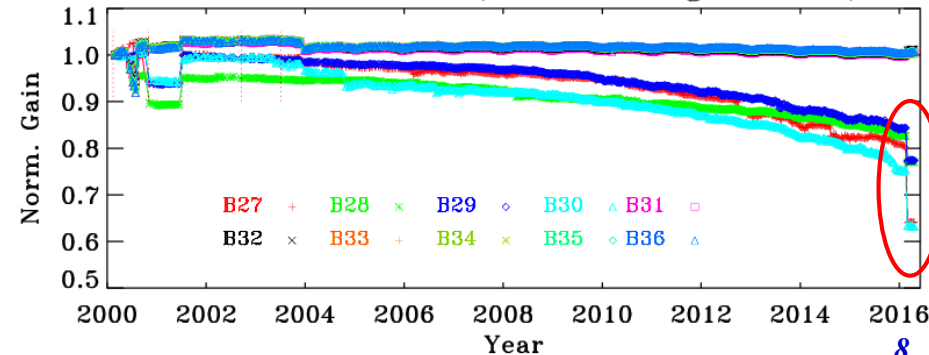
Terra MODIS MWIR (Band-Averaged, MS 1)



Aqua MODIS LWIR (Band-Averaged, MS 1)

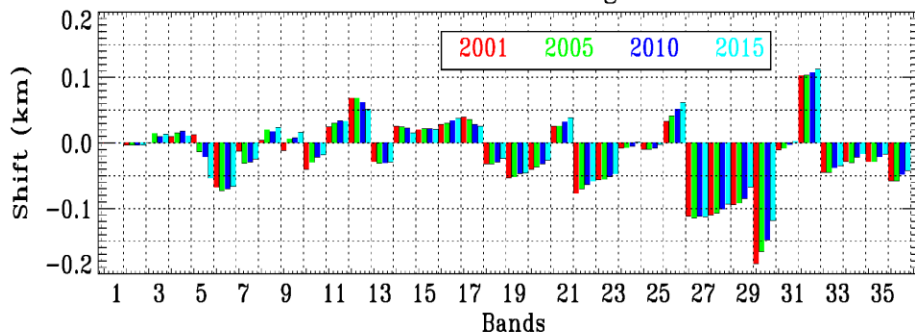


Terra MODIS LWIR (Band-Averaged, MS 1)

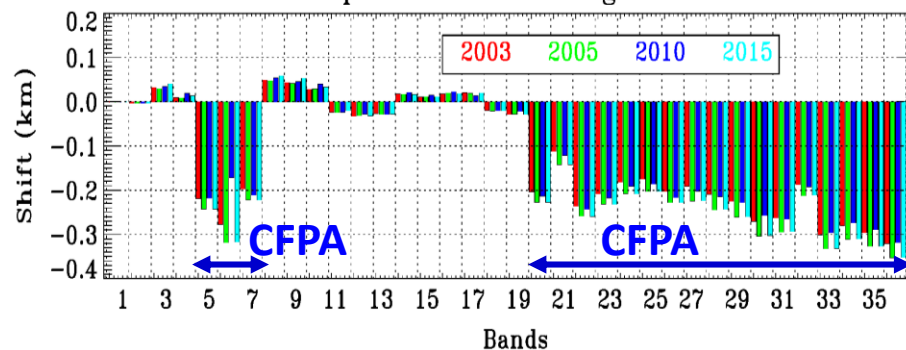


MODIS VIS/NIR Spatial Characterization Performance

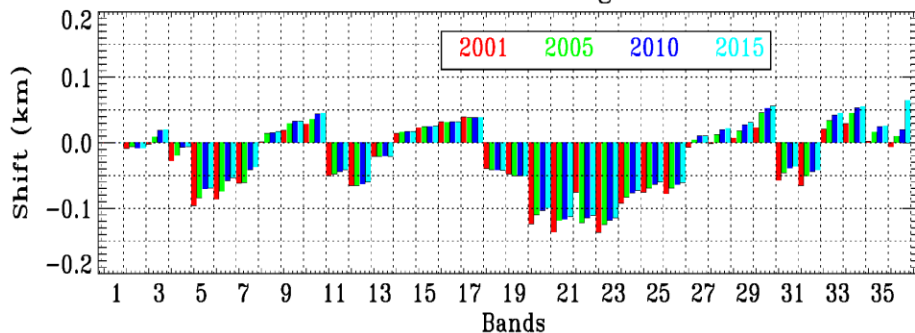
Terra BBR Shift Along-scan



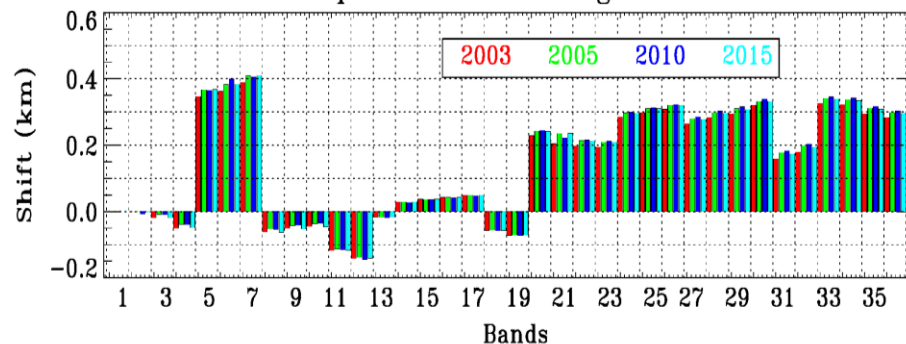
Aqua BBR Shift Along-scan



Terra BBR Shift Along-track



Aqua BBR Shift Along-track

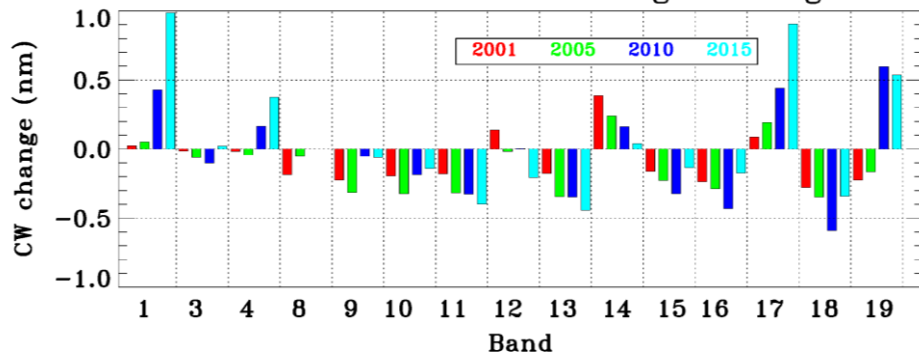


Terra BBR: within spec (± 0.1 km) for all band pairs (except for along scan B30 and B32)

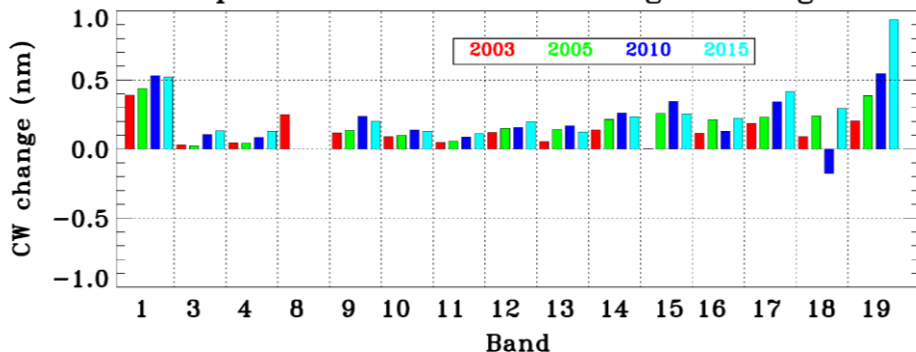
Aqua BBR: a known issue since pre-launch

MODIS VIS/NIR Spectral Characterization Performance

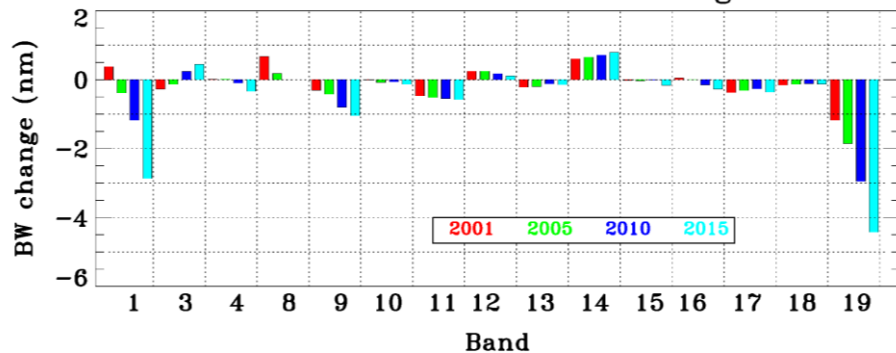
Terra MODIS Center Wavelength Changes



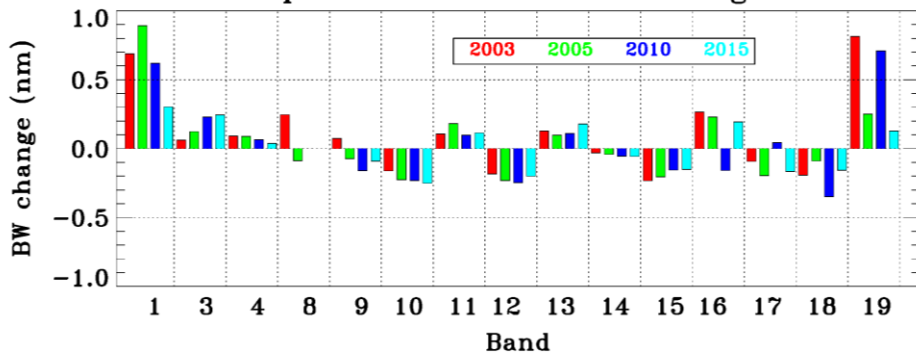
Aqua MODIS Center Wavelength Changes



Terra MODIS Bandwidth Changes



Aqua MODIS Bandwidth Changes



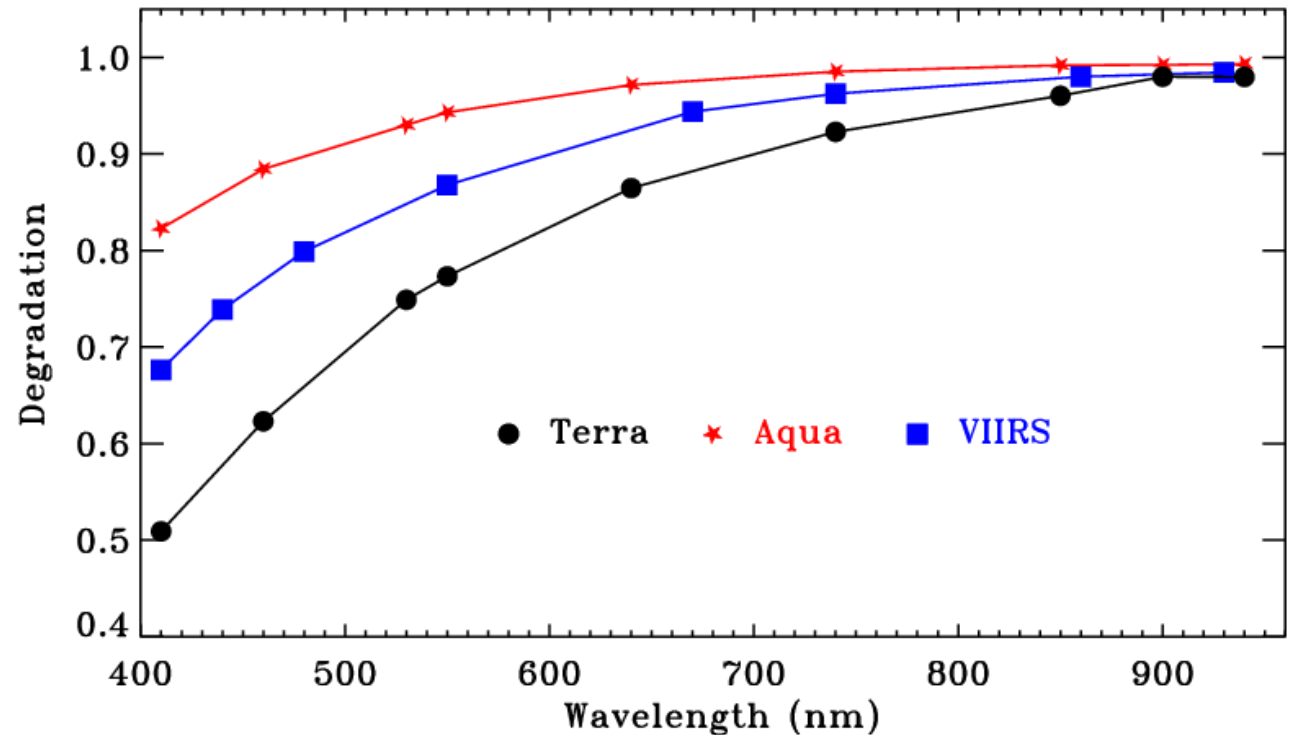
CW and BW changes are within 0.5 nm and 1.0 nm, respectively, for most VIS/NIR bands

Relatively large changes are observed for bands with broad bandwidths (bands 1, 18, 19)

MODIS and VIIRS SD Degradation



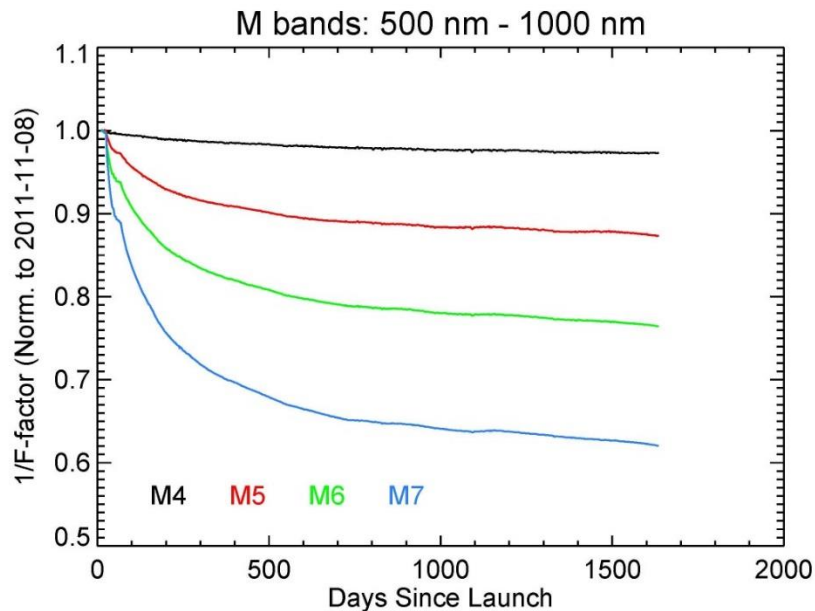
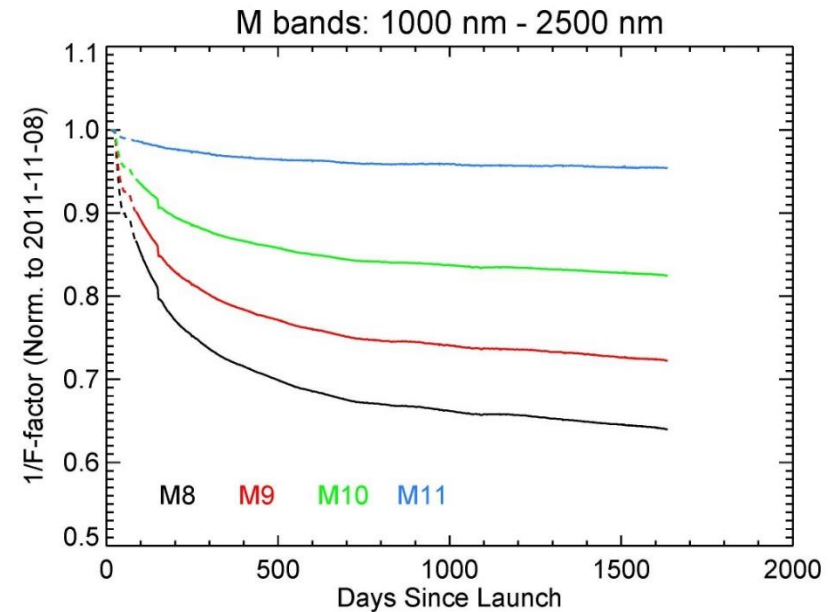
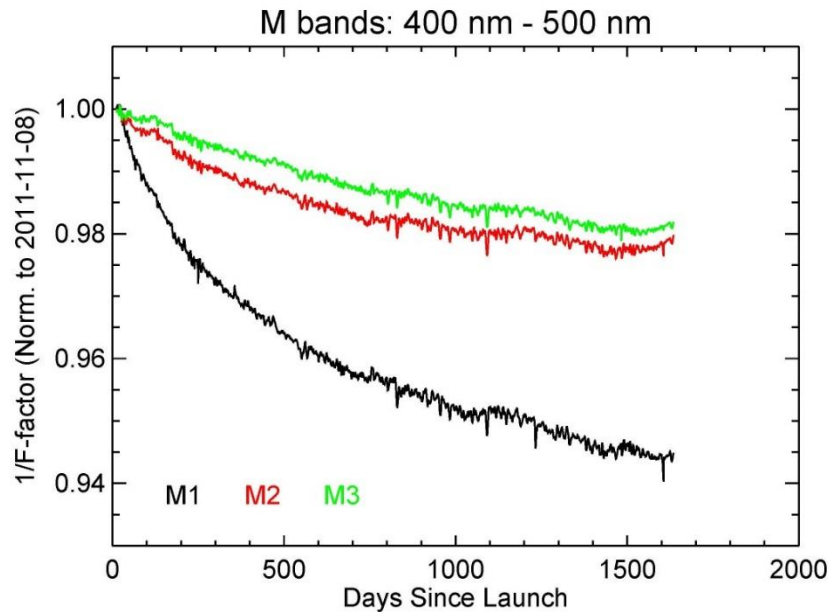
SD degradation monitored by the on-board SDSM



MODIS and VIIRS show similar wavelength dependent SD degradation

- Terra MODIS: SD door kept at open since 2003 (1999-present)
- Aqua MODIS: SD door opens only during SD/SDM calibration (2002-present)
- S-NPP VIIRS: no SD door (2011 to present)

VIIRS RSB Spectral Band Responses (from SD calibration)



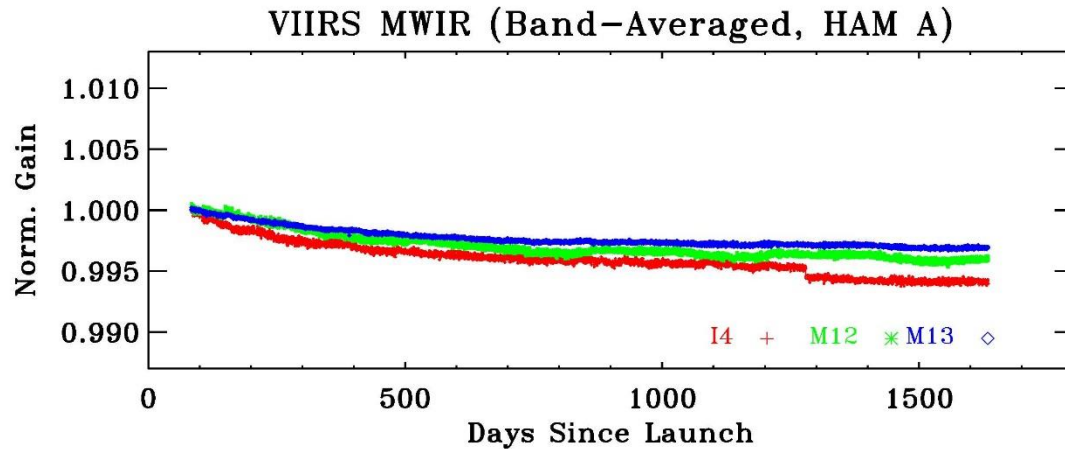
SD and lunar calibration at the same AOI

Small difference between SD and lunar calibration observed for a few bands

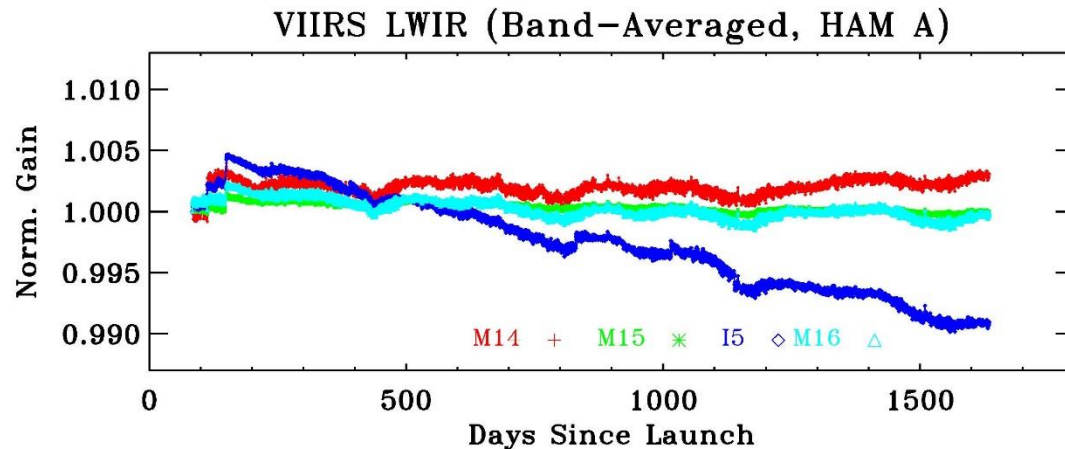
SD long-term trends normalized to lunar trends in latest calibration LUTs

Large changes in NIR/SWIR responses due to telescope mirror degradation → on-orbit modulated RSR

VIIRS TEB Spectral Band Responses (from BB calibration)



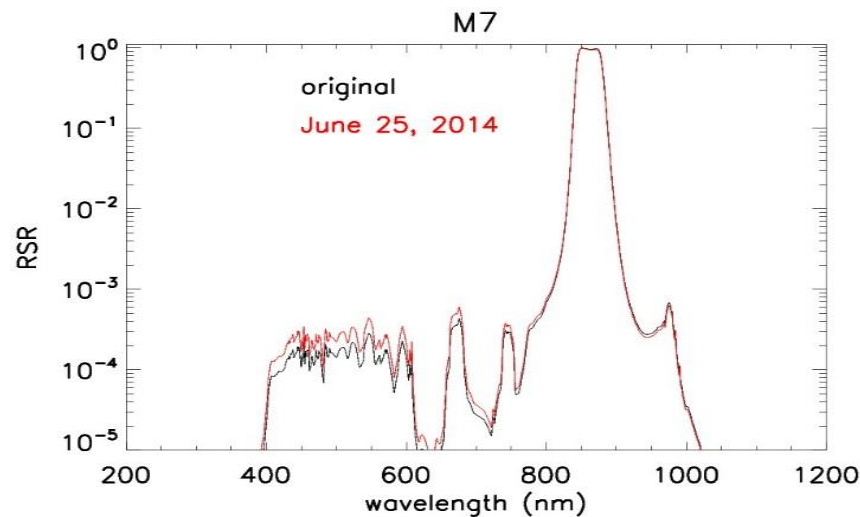
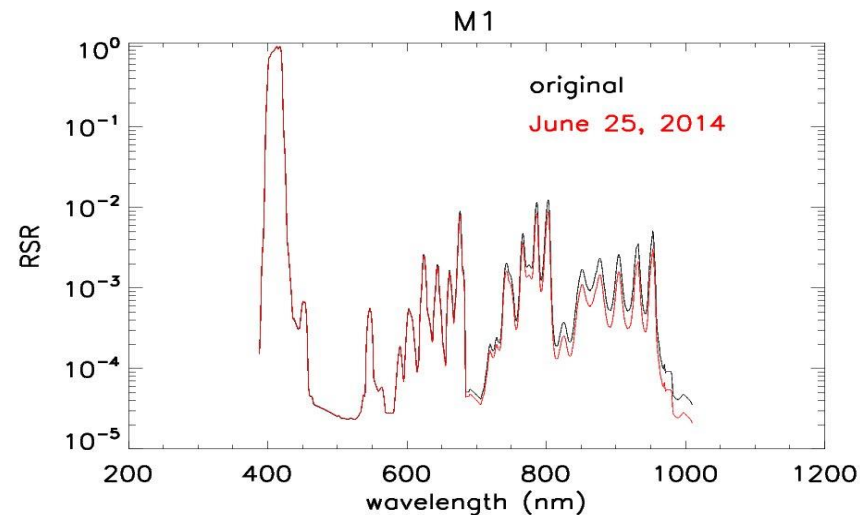
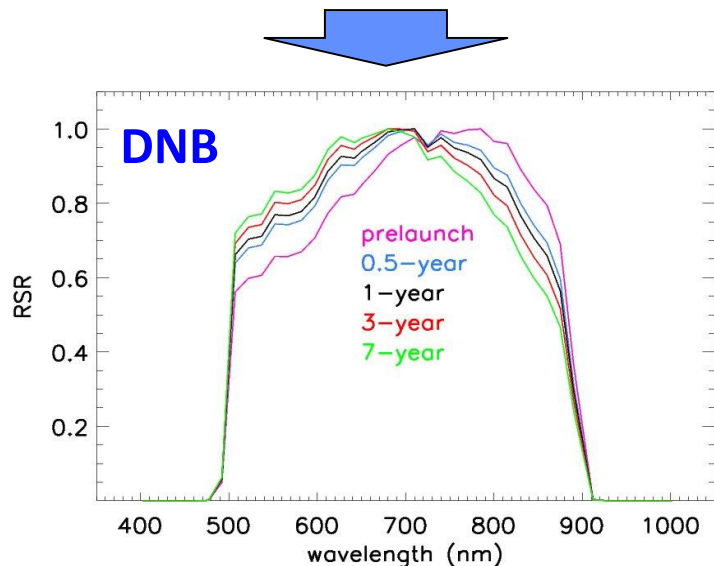
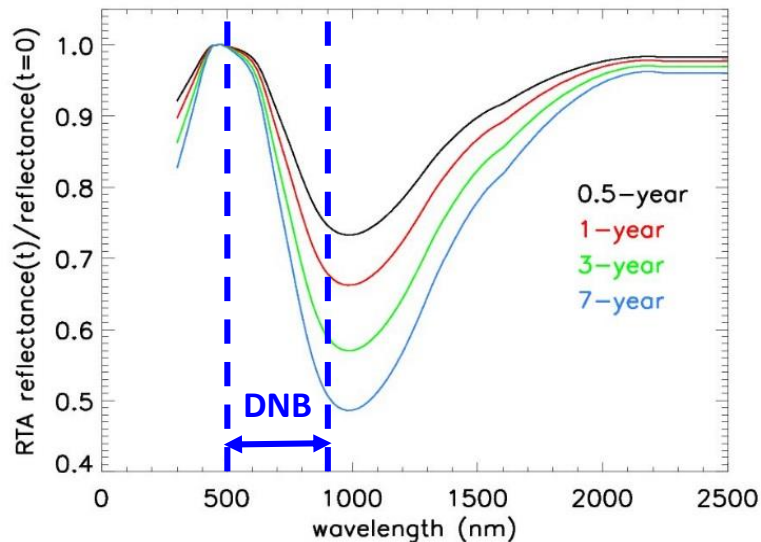
Excellent stability: less than 0.5-1% over 4+ years
(similar to Aqua MODIS)



MODIS has more TEB with wavelengths up to 14.5 μm

S-NPP VIIRS On-orbit Modulated RSR

λ dependent optics degradation
led to Modulated RSR



Small impact on bands with narrow
bandwidths and small OOB responses;
large impact on DNB (broad bandwidth)

Status of MODIS Level 1B Data Products (C6)

- Collection 6 (C6) L1B products released to public July 2012 for Aqua and Nov 2012 for Terra
- C6 L1B data can be downloaded from:
<http://ladsweb.nascom.nasa.gov/>
- New improvements since C6 release
 - ✓ *Correction applied to reduce Terra B5 (and potentially other SWIR bands) long-term drift as SDSM can only track SD degradation in VIS and NIR region*
 - ✓ *Forward updates of Aqua TEB nonlinear calibration coefficient (a_2)*
 - ✓ *Improved use of default gains for bands 33, 34, and 36 during BB WUCD*
 - ✓ *More bands included the earth view trending at different AOIs for RVS characterization (Terra band 10 added; Aqua bands 1-4 pending science team approval)*
 - ✓ *Polarization corrected trending for RVS characterization (under science evaluation by land team)*
 - ✓ *Terra PV LWIR electronic crosstalk correction (pending science team review)*

Status of S-NPP VIIRS SDR (NASA SIPS Support)

- **Land SIPS SDR reprocess using IDPS Code with VCST LUTs (C1.0 and C1.1)**
 - IDPS SDR/EDR codes Mx based version with LUTs input from VCST
 - 35 sets of LUTs for RSB (and DNB) have been delivered to Land SIPS for data reprocessing and SDR/EDR assessments in Collections 1.0 and 1.1.

Collection	Code base	# of LUTs	Delivery Time (year.month)	Improvements
C1.0	Mx6.3	5	2012.10 - 2013.01	Smoothed functions for SD degradation H-factor and calibration coefficients F-factor.
	Mx6.4	5	2013.04 - 2013.11	Updated SD/SDSM screen transmission, SD BRDF, RTA mirrors degradation model, and modulated RSRs.
C1.1	Mx7.2	25	2013.12 - 2016.02	Improved time-dependent modulated RSR, DNB stray light correction, H & F fitting functions.

- **Atmosphere SIPS SDR reprocess using IDPS Code with VCST LUTs**
 - Mission data reprocessing VIIRS SDR/EDR using Mx8.4 software in late 2014.
 - 9 sets of LUTs based on Mx8.4 code format have been delivered (Nov 2014 – Feb 2016) - same quality LUTs as those sent to Land C1.1.

Status of S-NPP VIIRS **L1B** (NASA SIPS Support)

- **NASA SIPS L1B/LUTs for mission reprocess (V1.1.0)**
 - VIIRS L1A and L1B software/LUT and data design are developed under NASA EDOS/SIPS.
 - SNPP VIIRS L0 data as the input for L1A software => 6-min L1A HDF5 data.
 - L1A and L1B calibration LUTs are the input for L1B software => Geolocation and L1B products including OBC.
 - First L1B software V1.1.0 was released in Jan 2016 for SIPS evaluation.
 - LUTs generations are based on corrected solar vector (error fix), on-orbit SD/SDSM screen transmission & SD BRDF, modulated RSR, and consistent fitting of mission data.

Collection	Code base	# of LUTs	Delivery Time (year.month)	Note
V1.1.0	L1B V1.1.0	2	2016.02 - 2016.03	Redesigned L1B software and LUTs format using input from NASA L1A data. L1B products are under evaluation.

Status of JPSS-1 VIIRS Calibration and Characterization

Pre-launch Calibration and Characterization:

- Sensor level testing
 - ✓ Ambient: 08/24/2013 - 01/19/2014
 - ✓ Pre-TVAC: 05/16/2014 - 07/16/2014
 - ✓ TVAC: 07/16/2014 - 10/30/2014
 - ✓ Post-TVAC: 11/24/2014 - 12/15/2014 (*PSR completed in Feb 2015*)
- Observatory level testing:
 - ✓ TVAC testing: June, 2016

Preparation for On-orbit Calibration (led by NOAA SDR team)

- LUTs development for SDR processing
 - ✓ “at launch” quality LUTs delivered in Dec 2015 (except for a few DNB LUTs to be developed after SC TVAC testing)

Launch in Jan 2017

- Intensive calibration and validation (ICV)
- **NASA effort similar to S-NPP VIIRS (TBR) – Impact to CERES?**

Status of JPSS-2 VIIRS Calibration and Characterization

Sensor Pre-launch Calibration and Characterization:

- Ambient Test Readiness Review (TRR): 03/24/2016
- Ambient phase: April-June 2016 (Started April 6th)
 - Key performance testing: RVS, NFR, SLR, SNR, Crosstalk, Polarization, RSR
- Thermal vacuum: February-August 2017
 - Key performance testing: Radiometric calibration, SNR, RSR, stability
- Pre-Ship Review (PSR): October 2017

Launch in July 2021

Summary

- Both Terra and Aqua MODIS continue to operate normally with all on-board calibrators capable of performing their design functions
- Changes in sensor responses (radiometric, spatial, and spectral) have been regularly monitored and corrections have been made to maintain data quality (via calibration LUTs – reprocessing/forward updates)
- Key challenging issues (RVS, polarization, crosstalk, noisy detectors) identified and characterized and mitigation plans developed for future improvements (C6 and beyond)
- S-NPP VIIRS overall performance has been satisfactory (mirror contamination induced optical degradation has significantly leveled off; modulated RSR derived and applied)
- Dedicated effort by VCST has been made in support of NASA PEATE/SIPS for generating consistent and research quality SDR/L1B and EDR
- J1 VIIRS SDR and EDR support for CERES needs to be addressed

POC:

- MODIS and VIIRS: Jack Xiong <xiaoxiong.xiong-1@nasa.gov>
- MODIS: Amit Angal <amit.angal@ssaihq.com>
- VIIRS (S-NPP) Vincent Chiang <kwofu.chiang@ssaihq.com>
- VIIRS (JPSS) Hassan Oudrari <hassan.oudrari-1@nasa.gov>

Backup Slides

Key Design Requirements of MODIS Spectral Bands

Primary Use	Band	Bandwidth (nm)	Spectral Radiance ¹	Required SNR	Primary Use	Band	Bandwidth (nm)	Spectral Radiance ¹	Required NEDT(K)
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128	Surface/Cloud Temperature	20	3.660 - 3.840	0.45 (300K)	0.05
	2	841 - 876	24.7	201		21	3.929 - 3.989	2.38 (335K)	0.2
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243		22	3.929 - 3.989	0.67 (300K)	0.07
	4	545 - 565	29	228		23	4.020 - 4.080	0.79 (300K)	0.07
	5	1230 - 1250	5.4	74	Atmospheric Temperature	24	4.433 - 4.498	0.17 (250K)	0.25
	6	1628 - 1652	7.3	275		25	4.482 - 4.549	0.59 (275K)	0.25
	7	2105 - 2155	1	110	Cirrus Clouds Water Vapor	26	1.360 - 1.390	6	150 (SNR)
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420	44.9	880		27	6.535 - 6.895	1.16 (240K)	0.25
	9	438 - 448	41.9	838		28	7.175 - 7.475	2.18 (250K)	0.25
	10	483 - 493	32.1	802	Cloud Properties	29	8.400 - 8.700	9.58 (300K)	0.05
	11	526 - 536	27.9	754	Ozone	30	9.580 - 9.880	3.69 (250K)	0.25
	12	546 - 556	21	750	Surface/Cloud Temperature	31	10.780 - 11.280	9.55 (300K)	0.05
	13	662 - 672	9.5	910		32	11.770 - 12.270	8.94 (300K)	0.05
	14	673 - 683	8.7	1087	Cloud Top Altitude	33	13.185 - 13.485	4.52 (260K)	0.25
	15	743 - 753	10.2	586		34	13.485 - 13.785	3.76 (250K)	0.25
	16	862 - 877	6.2	516		35	13.785 - 14.085	3.11 (240K)	0.25
Atmospheric Water Vapor	17	890 - 920	10	167		36	14.085 - 14.385	2.08 (220K)	0.35
	18	931 - 941	3.6	57	¹ Spectral Radiance values are (W/m ² -μm-sr)				
	19	915 - 965	15	250					

20 reflective solar bands (RSB) and 16 thermal emissive bands (TEB)

VIIRS (and MODIS) Spectral Bands

VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
I1	0.600 - 0.680	375	1	0.620 - 0.670	250
M5	0.662 - 0.682	750	13 or 14	0.662 - 0.672 0.673 - 0.683	1000 1000
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000
I2	0.846 - 0.885	375	2	0.841 - 0.876	250
M7	0.846 - 0.885	750	16 or 2	0.862 - 0.877 0.841 - 0.876	1000 250
M8	1.230 - 1.250	750	5	SAME	500
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000
I3	1.580 - 1.640	375	6	1.628 - 1.652	500
M10	1.580 - 1.640	750	6	1.628 - 1.652	500
M11	2.225 - 2.275	750	7	2.105 - 2.155	500
I4	3.550 - 3.930	375	20	3.660 - 3.840	1000
M12	3.660 - 3.840	750	20	SAME	1000
M13	3.973 - 4.128	750	21 or 22	3.929 - 3.989 3.929 - 3.989	1000 1000
M14	8.400 - 8.700	750	29	SAME	1000
M15	10.263 - 11.263	750	31	10.780 - 11.280	1000
I5	10.500 - 12.400	375	31 or 32	10.780 - 11.280 11.770 - 12.270	1000 1000
M16	11.538 - 12.488	750	32	11.770 - 12.270	1000

1 DNB:
L/M/HG
32 Agg. Modes

14 RSB:
0.41-2.3 μm

7 DGB:
M1-M5, M7,
and M13

7 TEB:
3.7-12.1 μm

VIIRS On-orbit Calibration Methodologies

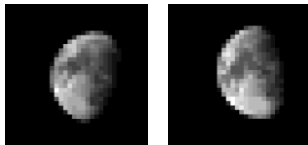
Stability Monitor



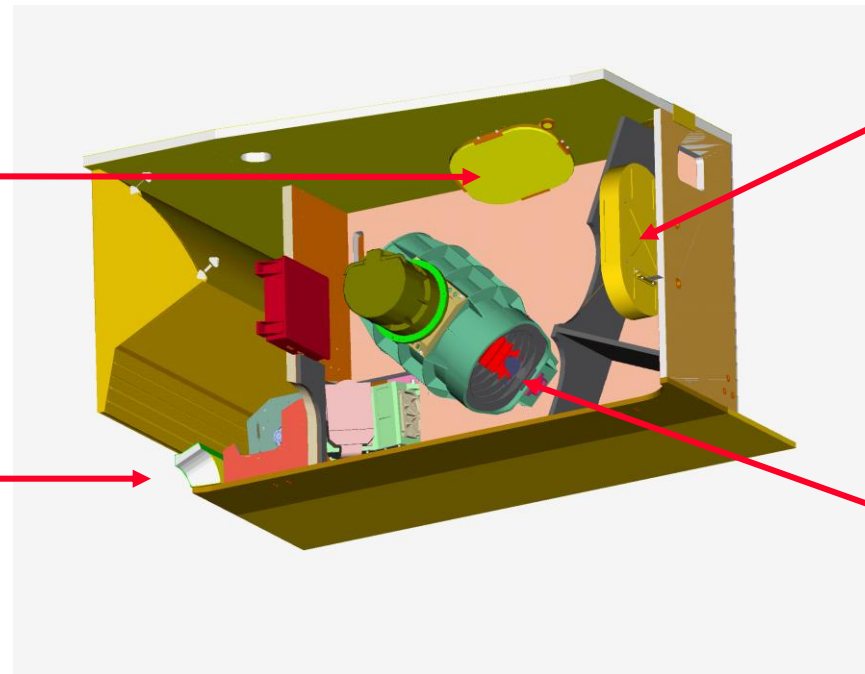
Solar Diffuser



Extended SV Port



VIIRS on-orbit operation and calibration are based on the experience and lessons from MODIS



Blackbody



Rotating Telescope Aft Optics and HAM